

INDOOR AIR QUALITY ASSESSMENT

**Emerson School Wing
100 Mechanic Street
Bolton, MA 01740**



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of building occupants, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality concerns at the Florence Sawyer School (FSS) and Emerson School Wing (ESW), 100 Mechanic Street, Bolton, Massachusetts. Complaints of poor airflow, exacerbation of allergies, odors and general indoor air quality concerns prompted the request. On April 11, 2006, a visit to conduct an assessment was made by Sharon Lee, an Environmental Analyst for CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Ms. Lee was accompanied by William Spratt, Facilities Director for the Nashoba Regional School District.

The FSS is a two-story brick building constructed in 1996 and consists of four wings built around a central courtyard. The school contains general classrooms, a library, a gymnasium, activity rooms and a cafeteria. The ESW is a two-story brick building constructed in 1922, with additions made in 1952 and 1972. The 1972 addition, which houses the majority of classrooms, was renovated in 1999. Windows throughout the ESW are openable. The ESW is the subject of this report, while the FSS is the subject of a separate report.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic

compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The ESW houses approximate 200 pre-kindergarten, third and fourth grade students, with approximately 25 staff members. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in 14 of 16 areas surveyed, indicating poor ventilation and air exchange in most areas of the ESW. It is important to note that at the time of the assessment several areas were empty or sparsely populated, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with increased occupancy.

Mechanical ventilation in the 1972 portion of the building is provided by rooftop air-handling units (AHUs). Fresh air is distributed via ceiling-mounted air diffusers. Air is ducted back to AHUs via ceiling-mounted return vents. Fresh air in the 1952 wing classrooms is supplied by unit ventilator (univent) systems (Picture 1). A univent is designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and return air through an air intake located at the base of the unit ([Figure 1](#)). Fresh and return air are mixed, filtered, heated and provided to classrooms

through an air diffuser located in the top of the unit. Many univents were found to be off or operating weakly at the time of the assessment. Please note, univents appeared to be original to the building (over 50 years old). Therefore, repair/replacement of parts may be difficult for units of this age.

Exhaust ventilation in classrooms is provided by ducted, grated wall vents powered by rooftop motors. At the time of the assessment, some exhaust vents were not operating, which can indicate they were deactivated or inoperable. In addition, a number of vents were obstructed by desks, bookcases and other items (Picture 3). In order for univents and exhaust vents to function properly, they must be activated and remain free of obstructions.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room, while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994). The date of the last balancing was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please consult [Appendix A](#).

Temperature measurements taken the day of the assessment ranged from 68° F to 73° F, which were within or slightly below the MDPH recommended comfort guidelines in some areas. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, temperature control is often difficult without operating the ventilation systems as designed (e.g., univents/exhaust vents deactivated/obstructed).

The relative humidity measurements taken the day of the assessment ranged from 17 to 23 percent, which were below the MDPH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A few areas had water-damaged ceiling tiles, which can indicate leaks from the roof or plumbing system. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired. Tiles glued directly to the ceiling system are more difficult to remove. For that reason, appropriate precautions should be taken when removing and replacing these tiles.

Breaches were observed between the counter and sink backsplashes in some classrooms. If not watertight, water can penetrate through these seams. Water penetration and chronic exposure of porous and wood-based materials can cause them to swell and show signs of water damage. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned

to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Plants were observed in several classrooms. In some areas, plants were observed on carpeting. Plants, soil and drip pans can serve as sources of mold growth, thus should be properly maintained. Over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants and related materials should also be located away porous materials (e.g. carpeting) to prevent damage and potential microbial growth in/on these materials.

Plants were observed to be growing against the foundation walls. The growth of roots against exterior walls can bring moisture in contact with the foundation. Plant roots can eventually penetrate, leading to cracks and/or fissures in the sublevel foundation. CEH staff also observed an open electrical box on the exterior of the building, which should be sealed to prevent water penetration and bird/insect habitation (Picture 4).

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM_{2.5}) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, CEH staff obtained measurements for carbon monoxide and PM_{2.5}.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On

the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu\text{g}/\text{m}^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu\text{g}/\text{m}^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 12 $\mu\text{g}/\text{m}^3$ (Table 1). PM2.5 levels measured indoors were between 4 to 14 $\mu\text{g}/\text{m}^3$ (Table 1), which were below the NAAQS level of 35 $\mu\text{g}/\text{m}^3$. Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. In an effort to identify materials that can potentially increase indoor TVOC concentrations, CEH staff examined classrooms for products containing these respiratory irritants. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Several other conditions that can affect indoor air quality were observed during the assessment. Of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were seen on windowsills, tabletops, counters, bookcases and desks. The amount of items stored provides a means for dusts, dirt and other potential respiratory irritants to accumulate. Many of the items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. In addition, fan blades to personal fans and exhaust

vents were occluded with dust. When reactivated, fans can aerosolize dust accumulated on fan blades. Backdrafting can cause aerosolization of dusts accumulated on exhaust vents.

Items hanging from ceiling tiles were observed in a few areas. Movement of ceiling tiles can result in the migration of dust, dirt, odors and other pollutants to occupied areas. Dust can be irritating to the eyes, nose and respiratory system. In addition, items hanging from the ceiling tile system can cause damage to the ceiling tile frame.

Large throw pillows and upholstered furniture (i.e., couches) were seen in a few classrooms. These upholstered items are covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. Furthermore, increased relative humidity levels above 60 percent can also perpetuate dust mite proliferation (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, 1994). It is also recommended that if upholstered furniture is present in schools, it should be professionally cleaned on an annual basis or every six months if dusty conditions exist (IICRC, 2000).

Lastly, in an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive

individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as [Appendix B](#) (NIOSH, 1998). Consider replacing tennis balls with alternative glides (Picture 5).

Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Operate both supply and exhaust ventilation continuously, independent of classroom thermostat control, during periods of school occupancy to maximize air exchange.
 2. Examine each univent for function to ascertain if an adequate air supply exists for each room. Check fresh air intakes for repair and increase the percentage of fresh air intake if necessary.
 3. Reactivate exhaust ventilation, make repairs as necessary.
 4. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
 5. Use openable windows/exterior doors in conjunction with classroom univents and exhaust vents to increase air exchange. Care should be taken to ensure windows and doors are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
 6. Consult a ventilation engineer concerning balancing of the ventilation systems.
- Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994).

7. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
8. Replace water-damaged ceiling tiles. Examine the areas above and around these tiles for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial. Removal of tiles directly adhered to the ceiling would be considered a renovation activity, since tile removal can release particulates and spores in particular, if the material is moldy. Replacement of ceiling tiles may involve glues that contain VOCs. In order to minimize occupant exposure, repairs should be done while the building is unoccupied.
9. Refrain from placing plants on porous materials (i.e., carpeting).
10. Examine sink countertop and backsplash areas for water damage and/or mold growth. Disinfect and replace as necessary. Seal breaches to prevent damage.
11. Remove plants from the foundation wall junction around the perimeter of the building. Seal the junction with an appropriate sealant.
12. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.

13. Clean accumulated dust from univents, exhaust vents and blades of personal fans periodically to prevent excessive dust build-up.
14. Clean upholstered furniture on the schedule recommended in this report. If not possible/practical, remove upholstered furniture from classrooms.
15. Consider replacing tennis balls with alternative “glides”.
16. Consider adopting the US EPA (2000b) document, *Tools for Schools*, in order to provide self-assessment and maintain a good indoor air quality environment. This document is available at: <http://www.epa.gov/iaq/schools/index.html>.
17. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH’s website: http://mass.gov/dph/indoor_air

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Picture 1



Classroom univent, circa 1950s model

Picture 2



Univent fresh air intake

Picture 3



Wall-mounted exhaust vent behind desk

Picture 4



Open electrical box

Picture 5



Alternative “glides” for chair legs that can be used in place of tennis balls

Emerson School Wing

100 Mechanic Street, Bolton, MA 01740

Indoor Air Results

Date: 4/11/2006

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		58	30	479	ND	ND	12				
1	21	73	21	1314	ND	ND	7	Y # open: 0 # total: 2	Y ceiling	Y ceiling	DEM, PF, TB, UF
Computer lab	19	73	20	1127	ND	ND	5	N	Y ceiling	Y ceiling	
2	1	71	18	760	ND	ND	4	Y # open: 0 # total: 2	Y ceiling	Y ceiling	#WD-CT: 4, DEM, PS, TB, clutter, items hung from ceiling, plants
3	1	68	20	832	ND	ND	5	Y # open: 0 # total: 2	Y ceiling	Y ceiling	Hallway DO, DEM, UF, clutter
4	16	70	23	1219	ND	ND	9	Y # open: 1 # total: 2	Y ceiling	Y ceiling	DEM
5	1	70	21	1081	ND	ND	7	Y # open: 0 # total: 2	Y ceiling	Y ceiling	Hallway DO, DEM

ppm = parts per million

µg/m3 = micrograms per cubic meter

AD = air deodorizer

AP = air purifier

aqua. = aquarium

AT = ajar ceiling tile

BD = backdraft

CD = chalk dust

CP = ceiling plaster

CT = ceiling tile

DEM = dry erase materials

design = proximity to door

DO = door open

FC = food container

GW = gypsum wallboard

MT = missing ceiling tile

NC = non-carpeted

ND = non detect

PC = photocopier

PF = personal fan

plug-in = plug-in air freshener

PS = pencil shavings

sci. chem. = science chemicals

TB = tennis balls

terra. = terrarium

UF = upholstered furniture

VL = vent location

WD = water-damaged

WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
 600 - 800 ppm = acceptable
 > 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
 Relative Humidity: 40 - 60%

Table 1 (cont.)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
6	1	73	21	1132	ND	ND	8	Y # open: 0 # total: 2	Y ceiling	Y ceiling	Plants on carpet, DEM, PF, plants
7	0	72	20	901	ND	ND	6	Y # open: 0 # total: 4	Y ceiling	Y ceiling	DEM, clutter
Pre-K	5	72	21	1233	ND	ND	7	N	Y ceiling	Y ceiling	Breach sink/counter
8	0	73	20	1147	ND	ND	14	Y # open: 0 # total: 2	Y ceiling	Y ceiling	DEM, TB, UF
10	0	72	19	1009	ND	ND	7	N	Y ceiling	Y ceiling	Hallway DO, breach sink/counter, DEM, clutter, plants
9	0	70	19	877	ND	ND	8	N	Y ceiling	Y ceiling	DEM, plants
Gym	20	70	17	745	ND	ND	8	N	Y ceiling	Y wall Dirt/debris	

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									Supply	Exhaust	
OT/PT	1	72	22	822	ND	ND	4	Y # open: 0 # total: 5	Y univent	Y wall	Window-mounted AC, DEM
Extended day room	0	71	21	812	ND	ND	7	Y # open: 1 # total: 5	Y univent Off	Y wall	Hallway DO
End room (1952 wing)	4	70	23	1019	ND	ND	8	Y # open: 0 # total: 2	Y univent ceiling		#WD-CT:1

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